RAIL - HIGHWAY
IMPACT EVALUATION
STUDY

PREPARED BY

MONTANA DEPARTMENT OF HIGHWAYS

AND

MONTANA DEPARTMENT OF COMMERCE

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RAIL - HIGHWAY IMPACT STUDY

I. Introduction

A. Purpose

The intent of this study is to establish a process mutually agreed upon by the Montana Department of Highways (DOH) and the Montana Department of Commerce (DOC) in which highway impacts resulting from rail line abandonments can be quantified, evaluated and mitigated. In order to accomplish this objective, a sequential methodology needs to be established which specifies required information input and delineates each agency's responsibilities with respect to these input needs. The culmination of this process should be an estimate of highway costs resulting from additional truck traffic caused by rail line abandonment, consideration of mitigating of alternatives, and establishment of priorities.

B. Rail Plan, Abandonment, and Notification Process

1. Rail Plan

The Transportation Division of the DOC, in cooperation with the Federal Railroad Administration, originally prepared a State Rail Plan pursuant to Section 803 of the Railroad Revitalization and Regulatory Reform Act of 1976 (4 R Act). This initial Rail Plan was completed in August of 1979. It classified all rail lines

within the state, assessed light density lines, prioritized light density lines, and established the first rail system plan for the State of Montana.

In conformance with the 4 R Act which requires states to prepare an annual update each year, a supplement to the initial rail plan was prepared in 1980.

In July of 1982, with the assistance of Wilbur Smith and Associates, Inc., the DOC/Transportation Division completed a major revision entitled "Montana Rail Plan 1982 Annual Update" which provided an in-depth study of all branchlines not addressed in the initial Rail Plan. Currently, a 1983 supplement of the Montana Rail Plan prepared by the DOC/Transportation Division has been submitted to the Federal Railroad Administration for approval. The importance of the State Rail Plan stems from the fact that it represents Montana's policy regarding the entire state rail system. The rail plan is established through a complete line assessment independent of the three railroads providing service in the state. The Rail Plan, therefore, serves as a base from which to evaluate actions proposed by these railroads operating in Montana. Sources of shipping information for the State Rail Plan include

shippers surveys, railroad commodity movement reports and Montana Grain Movement Reports provided by the Montana Department of Agriculture.

2. <u>Rail Abandonment Process and Notification</u>

Pursuant to federal law, all railroads operating within a state must submit annually to that state's responsible rail administration agency a System Diagram Map indicating line status. Line status notifies the State Rail Administration Agency for the most part the intent of each railroad regarding its lines. Line status is grouped within five categories which are listed as follows:

<u>DEFINITION OF CATEGORIES</u>

Category 1 - All lines or portions of lines which the carrier anticipates will be the subject of an abandonment or discontinuance application to be filed within the 3-year period following the date upon which the diagram, or any amended program, is filed with the Interstate Commerce Commission (ICC).

Category 2 - All lines or portions of lines potentially subject to abandonment which the carrier has under study believes may be the subject of a future abandonment application because of either anticipated operating losses or excessive rehabilitation costs.

Category 3 - All lines or portions of lines for which an

abandonment or discontinuance application is pending before the ICC on the date upon which the diagram, or any amended diagram, is filed with the ICC.

Category 4 - All lines or portions of lines which are being operated under the rail service continuation provisions of Section 1a(6)(a) of the Act or of Section 304(c)(2) of the Regional Rail Reorganization Act of 1973, as amended, on the date upon which the diagram, or any amended diagram, is filed with the ICC.

Category 5 - All other lines or portions of lines which the carrier owns and operations, directly or indirectly.

For purposes of this study only lines falling within Categories 1, 2, or 3 will be considered. Additional information provided by each railroad in their systems diagram map includes a description of each rail portion proposed or anticipated to be proposed for abandonment along with a illustrative map graphically depicting the line in question.

II. Highway Impact Evaluation Process

The following presents the Highway Impact Evaluation Process. Basic elements or steps of the process are each described along with background information in order for the user or reader to better understand the purpose of each element. Also included in each element is required data input and agency responsibility for providing the data.

Portions of the proposed evaluation process appear with each basic element. To differentiate between the evaluation process and background information, two different type styles were used.

A copy of the overall evaluation process appears in aggregate form in the Appendix as Attachment A.

A. <u>Study Initiation</u>

<u>PROPOSED PROCESS</u>

I. <u>Initiate Proposed Branchline Highway Impact Study</u>

A. Develop memorandum indicating branchline or branchlines to be studied.

Include: (1) Name of branchline

(2) Miles of line proposed for abandonment

(3) Map indicating location of line

(4) Railroad operator

(5) Present category status

<u>Responsibility</u> - In most cases, the DOC/Transportation Division will initiate the Highway Impact Study, however, in some cases, the Montana Department of Highways may wish to do so.

II. <u>Correlation to State Rail Plan</u>

A. Provide narrative and appropriate data included in the State Rail Plan which pertains to the branchline in question.

<u>Responsibility</u> - The DOC/Transportation Division will

provide information with respect to branchline correlation to the State Rail Plan.

B. Commodity Movement of Branchline

Background - The magnitude of the highway impact from loss of rail service for the most part will result from the commodities presently shipped over that line. It is, therefore, important to know the type of product shipped, quantity shipped, its origin on the branchline and destination. This information can be collected through a variety of methods including shipper surveys, railroad waybills, railroad commodity reports, and grain movement reports.

PROPOSED PROCESS

III. Input Commodity Movement of Branchline Data

A. Develop present branchline commodity movement data (two year average is preferred) with respect to:

(1) type of produce shipped

(2) quantity shipped

(3) origin - point of loading

(4) destination - point of unloading

Responsibility - The DOC/Transportation Division will develop the present branchline commodity movement data.

C. Highway System in Abandonment Area

Background - Of particular importance in determining

the impact of loss of rail service is to examine the characteristics of the highway system in which the commodities will have to be transported over. Highway characteristics necessary for input include: (1) highway functional classification, (2) existing traffic volume, and (3) roadway condition.

PROPOSED PROCESS

IV. Determine the highway functional classification system in the area affected by the proposed rail abandonment with respect to rural principal arterials, rural minor arterials, and rural major and minor collectors. This information will be also used later in the assignment process.

Responsibility - The DOH/Program Development Division will provide this information in map form.

V. Provide existing traffic volume information by section for each highway within the affected area.

Responsibility - The DOH/Program Development Division will provide this information from their traffic count data both in terms of total traffic and commercial truck traffic if available.

VI. Determine the condition of roadways within each affected area.

Responsibility - The DOH/Program Development Division will provide highway sufficiency information on all roadways in a rail abandonment impact area if available.

D. Highway Assignment

Background - It is necessary to establish which route over the highway network the trucks will take travelling from their point of origin to their point of destination. This assignment process can be estimated through the use of a computer or accomplished through a hand assignment. Due to resource constraints, it is anticipated for the present time this process will be performed by hand.

PROPOSED PROCESS

VII. Convert quantities of product shipped to average annual tons, average annual pounds and number of truck loads. In the case of grain trucks, payloads should take into account both farm trucks and custom grain hauling trucks. Use, if possible, local survey information, however, previous weight surveys or typical payload weight data for farm trucks and custom grain trucks may be used. If a local survey is conducted, truck weight information should be set up as follows:

Loaded

Total Loaded Weight	Front Wheel Weight	Tandem Wheel Weight
-	-	-
-	-	-
-	-	-

Average Loaded Weight	Average Front Wheel Weight	Average Tandem Wheel Weight
Empty		
Empty Truck Total Weight	Front Wheel Weight	Tandem Wheel Weight
-	-	-
-	-	-
-	-	-
Average Empty Truck Weight	Average Front Wheel Weight	Tandem Wheel Weight

Average total weight__________

Average truck weight__________

Average load weight__________

- In order to obtain the number of truck round trips required to haul commodities divide average total commodities to be hauled by the average truck load weight.

Responsibility - The DOC/Transportation Division will convert product quantities shipped to average annual tons, average annual pounds and number of truck loads.

VIII. Estimate the probable route or routes that will be utilized by trucks moving the additional quantities from loss of rail service from their origin to their destination. In most cases, the shortest distance will be used. All assumptions

will be documented.

Responsibility - The DOC/Transportation Division will perform these assignments by hand. (Refer to Appendix - Attachment B)

E. Highway Design Characteristics

Background - After the highway assignment is made, it is necessary to determine the design characteristics of the highways affected.

PROPOSED PROCESS

IX. Establish for each affected highway section within the area design information relative to design year, existing and projected total traffic estimate used in its design, percent truck traffic, directional factor and its design 18 K load factor.

Responsibility - The DOH/Program Development Division will provide this information

F. Highway Impact Determination

Background - The DOH/Program Development Division with the assistance of the DOC/Transportation Division after considerable investigation scheduled on a method for determining the impact of rail commodity loads on highways and is reflected in the remaining five steps of this process. This approach was originally developed by John M. Mason, Jr. Ph.D, P.E. from Texas A

& M University. A summary of Mr. Mason's research appeared in the March 1983 issue of the ITE Journal in an article entitled, "Effects of Oil Field Development on Low Volume Roadways: An Overlooked Energy Related Cost." Detailed procedures for evaluating oil field impacts which appear to be synonymous with evaluating rail branchline abandonment impacts are included in three separate research reports available from the Texas A & M University system. A copy of the article appearing in the ITE Journal is included in the Appendix as Attachment C.

PROPOSED PROCESS

X. <u>Determine the daily 18K equivalent wheel load (E.W.L.) design of the existing highway facility</u> by road section. The daily 18 K equivalent wheel load (E.W.L.) of the highway impacted can be determined by substituting the design numerical values for existing and projected traffic, percent truck traffic, directional factor and design 18 K load factor determined in Step IX into the following formula:

$$\frac{\text{20 year design life traffic average}}{2} \; X \; \text{directional factor} \; X \; \text{percent of all trucks} \; X \; \text{Design 18K load factor} = \text{Daily design 18K E.W.L.}$$

Refer to Appendix - Attachment D for methodology.

<u>Responsibility</u> - The DOC/Transportation Division will subsitute the design values and determine the highway daily design 18K E.W.L.

XI. Determine the 18K Equivalent Wheel Load caused due "extra" trucks

(a) refer to Step VII to determine annual roundtrips required to move commodity.

(b) multiply the annual additional truck roundtrips required by the average 18K Equivalent Loading factor found on Page 6 of the Surface Design Manual (Appendix - Attachment E) to determine the 18K E.W.L. caused by the extra trucks hauling the additional load over the highway. Refer to Appendix - Attachment D for methodology.

Responsibility - The DOC/Transportation Division will perform the necessary computations under this step.

XII. Calculate the number of days of design life lost due to the additional 18 K loads.

(a) Refer to Appendix - Attachment D for example of methodology. Divide for each highway section the 18K E.W.L. due because of the extra trucks hauling the additional load (Section XI(b) by the highway facility Design Daily 18K E.W.L. (Section X) to determine the number of days of design life lost due to the additional loads.

XIII. Establish years of pavement life with the "extra" trucks for each highway section.

(Assume 20 year pavement without "extra" trucks) to determine years of pavement life with

the additional load using the following equation:

$$\text{years of pavement life with additional load} = 20 - \frac{(\text{days design life lost} \times 20)}{365 \text{ days}}$$

Refer to Appendix - Attachment D for example of methodology.

XIV. <u>Establish years until seal and cover would be required</u> as a result of the "extra" trucks for each highway section. (Assumes seal and cover would not be required for 10 years without "extra" trucks) To determine years until a seal and cover would be required with the additional load use the following equation.

$$\text{years till seal and cover required with additional load} = 10 - \left(\frac{\text{days design life cost} \times 10}{365 \text{ days}}\right)$$

Refer to Appendix - Attachment D for example of methodology.

XV. <u>Determine the annual pavement cost impact as a result of the additional load on the highway for each highway section</u>. The annual pavement cost can be determined using the following equation:

$$\text{annual pavement cost} = \text{capital recovery factor} \left[\text{pavement cost/mile} + \left(\text{rehab cost/mile} \times \text{present worth factor} \right) \right]$$

Refer to Appendix - Attachment C for an explanation of the Capital Recovery Factor and equation.

Appendix - Attachment D, Page 2 provides a methodology example in the use of the equation to determine annual pavement cost.

III. Consideration of Alternatives

Once the highway impact costs have been determined, it is then necessary to establish what alternatives are available to mitigate the rail service loss impacts. Three basic alternatives are identifiable:

(1) allow the abandonment of rail service to take place while requiring the railroad to mitigate impacts to the surrounding highway system,

(2) allow the rail line abandonment to take place and have the Montana Department of Highways mitigate impacts through available state funding, or

(3) restore rail service through some form of subsidizing effort.

Normally the greater the amount of commodities hauled over a rail line the more feasible and necessary it is to restore rail service and the greater would be the impact to the highway system. In this case, it may be more of a benefit for the shippers and the Montana Department of Commerce to assist in restoring rail service to the branchline thereby keeping the additional truck traffic load off the local highway network. If the amount of commodities traveling over the branchline is small, then the highway impact would be less severe and may be better handled through the normal highway program process. It is important to make the determination as to what action needs to be taken early before the rail abandonment is considered

by the Public Service Commission and Interstate Commerce Commission. Therefore, it is recommended that once highway impacts with respect to a branchline abandonment are determined, the Montana Department of Highways and the Montana Department of Commerce should through some form of agreement or documentation agree as to what course of action should be taken.

IV. Establishment of Priorities

Once a course of action has been established between the Montana Department of Highways and the Montana Department of Commerce, it will be necessary to expedite or place in high priority required highway projects and rail projects. According to prescribed rules established by the Interstate Commerce Commission, it is possible for a branchline abandonment to take place within four to six months which is significantly shorter than a highway construction project (five to seven years) or rail construction project (two to three years) to be completed. Due to these time differences, highways which are substantially impacted and have critical sufficiency ratings should be considered for receiving emergency construction status.

V. Conclusion

Highway and rail systems throughout the United States are designed to accommodate specific levels of commercial traffic. With respect to highways, its design will serve

its original intent for some period of time. However, when subjected to a traffic condition well beyond its intended purpose, its life is substantially shortened. Unfortunately, the railroad in relieving itself of its unprofitable burden by abandoning branchlines, places the burden of cost on state agencies already over obligated with a number of other infra-structure responsibilities. This highway impact evaluation process, if performed properly, will result in estimates of the cost of rail abandonments on the state and local highway network that have a substantial degree of accuracy. Up to the present time, such estimates have not had sufficient accuracy.

APPENDIX

ATTACHMENT A

PROPOSED PROCESS

I. Initiate Proposed Branchline Highway Impact Study

A. Develop memorandum indicating branchline or branchlines to be studied.

Include: (1) Name of branchline

(2) Miles of line proposed for abandonment

(3) Map indicating location of line

(4) Railroad operator

(5) Present category status

Responsibility - In most cases, the Transportation Division of the Montana Department of Commerce will initiate the Highway Impact Study, however, in some cases, the Montana Department of Highways may wish to do so.

II. Correlation to State Rail Plan

A. Provide narrative and appropriate data included in the State Rail Plan which pertains to the branchline in question.

Responsibility - The DOC/Transportation Division will provide information with respect to branchline correlation to the State Rail Plan.

III. Input Commodity Movement of Branchline Data

A. Develop present branchline commodity movement data (two

year average is preferred) with respect to:

(1) type of product shipped

(2) quantity shipped

(3) origin - point of loading

(4) destination - point of unloading

Responsibility - The DOC/Transportation Division will develop as input present branchline commodity movement data.

IV. Determine the highway functional classification system in the area affected by the proposed rail abandonment with respect to rural principal arterials, rural minor arterials, and rural major and minor collectors. This information will also be used later on in the assignment process.

Responsibility - The DOH/Program Development Division will provide this information in map form.

V. Provide existing traffic volume information by section for each highway within the affected area.

Responsibility - The DOH/Program Development Division will provide this information from their traffic count data both in terms of total traffic if available.

VI. Determine the condition of roadways within each affected area.

Responsibility - The DOH/Program Development Division will

provide highway sufficiency information on all roadways in a rail abandonment impact area if available.

VII. Convert quantities of product shipped to average annual tons, average annual pounds and number of truck loads. In the case of grain trucks, payloads should take into account both farm trucks and custom grain hauling trucks. Use, if possible, local survey information, however, previous weight surveys or typical payload weight data for farm trucks and custom grain trucks may be used. If a local survey is conducted, truck weight information should be set up as follows:

Loaded

Total Loaded Weight	Front Wheel Weight	Tandem Wheel Weight
-	-	-
-	-	-
-	-	-
Average Loaded Weight	Average Front Wheel Weight	Average Tandem Wheel Weight

Empty

Empty Truck Total Weight	Front Wheel Weight	Tandem Wheel Weight
-	-	-
-	-	-
-	-	-
Average Empty Truck Weight	Average Front Wheel Weight	Tandem Wheel Weight

Average total weight__________

Average truck weight__________

Average load weight__________

In order to obtain the number of truck round trips required to haul commodities, divide average total commodities to be hauled by the average truck load weight.

Responsibility - The DOC/Transportation Division will convert product quantities shipped to average annual tons, average annual pounds and number of truck loads.

XIII. Estimate the probable route or routes that will be utilized by trucks moving the additional quantities from loss of rail service from their origin to their destination. In most cases, the shortest distance will be used. All assumptions will be documented.

Responsibility - The DOC/Transportation Division will perform these assignments by hand. (Refer to Appendix - Attachment B)

IX. Establish for each affected highway section within the area design information relative to design year, existing and projected traffic estimate used in its design relative to total traffic, percent truck traffic, directional factors and its design 18 K load factor.

Responsibility - The DOH/Program Development Division

will provide this information.

X. Determine the daily 18K equivalent wheel load (E.W.L.) design of the existing highway facility by road section. The daily 18K E.W.L. of the highway impacted can be determined by substituting the design numeral values for existing and projected traffic, percent truck traffic, directional factor and design 18 K load factor determined in Step IX into the following formula.

$$\frac{\text{20 year design life traffic average}}{2} \times \text{directional factor} \times \text{percent of all trucks} \times \text{Design 18K load factor} = \text{Daily design 18K E.W.L.}$$

Refer to Appendix - Attachment D for methodology.

Responsibility - The DOC/Transportation Division will substitute the design values and determine the highway daily design 18K E.W.L.

XI. Determine the 18K Equivalent Wheel Load caused due to "extra trucks.

(a) refer to Step VII to determine annual round truck trips required to move commodity.

(b) multiply the annual additional truck round trips required by the average 18K Equivalent Loading factor found on page 6 of the Surface Design Manual (Appendix - Attachment E) to determine the 18K E.W.L. caused by the extra trucks hauling the additional load over the highway. Refer to Appendix - Attachment D for methodology.

Responsibility - The DOC/Transportation Division will perform the necessary computations under this step.

XII. Calculate the number of days of design life lost due to the additional 18K loads.

(a) refer to Appendix - Attachment D for example of methodology. Divide for each highway section the 18K E.W.L. due because of the extra trucks hauling the additional load (Section XI (b) by the highway facility Design Daily 18K E.W.L. (Section X) to determine the number of days of design life lost due to the additional loads.

Responsibility - The DOC/Transportation Division will perform the necessary calculations to determine the number of days of design life lost.

XIII. Establish years of pavement life with the "extra" trucks for each highway section. (Assumes 20 year pavement without "extra" trucks) to determine years of pavement life with the additional load use the following equation:

$$\text{years of pavement life with additional load} = 20 - \left(\frac{\text{Days Design Life Lost X 20}}{\text{365 days}}\right)$$

Refer to Appendix - Attachment D for example of methodology.

Responsibility - The DOC/Transportation Division will do this computation.

XIV. Establish years until seal and cover would be required

As a result of the "extra" trucks for each highway section. (Assumes seal and cover would not be required for 10 years without "extra" trucks) to determine years until a seal and cover would be required with the additional load use the following equation.

$$\text{years till seal and cover required with additional load} = 10 - \left(\frac{\text{Days Design Life Lost X 10}}{\text{365 days}}\right)$$

Refer to Appendix - Attachment D for example of methodology.

Responsibility - The DOC/Transportation Division will complete this computation.

XV. Determine the Annual Pavement Cost impact as a result of the additional load on the highway for each highway section. The annual pavement cost can be determined using the following equation:

$$\text{annual pavement cost} = \text{capital recovery factor} \left[\text{pavement cost/mile} + \left(\text{rehab cost/mile} \times \text{present worth factor} \right) \right]$$

Refer to Appendix - Attachment C for an explanation of the Capital Recovery Factor and equation. Appendix - Attachment D, Page 2 provides a methodology example in the use of the equation to determine annual pavement cost.

Responsibility - The DOC/Transportation Division will perform the necessary calculations to determine the annual pavement cost impact.

TRUCK TRAFFIC ASSIGNMENT

The DOC/Transportation Division performed a truck traffic assignment in August of 1983 with respect to possible highway impacts resulting from 1983 system diagram proposed abandonments under ICC categories 1 and 3. Narrative documentation pertaining to assumptions, origins, and destinations, quantitative shipped, number of truck loads and highway assignment are presented as follows. Not included are maps illustrating the highways affected.

I. Highway impacts as the result of the abandonment of all lines in ICC Categories 1 and 3.

A. Assumptions

1. All grain figures are based on 1982 Montana Department of Agriculture grain movement data. ICC category information is taken from the June 1983 BN System Diagram Map.
2. The estimates assume that the abandonment of the rail line in question does not cause the elevator on the line to close down. The number of semi trucks (in 1982) loaded out of existing elevators is not considered in this study since they would already be included in 1982 truck volume figures.
3. These estimate measure the increase in farm and semi truck traffic as the result of an abandonment.
4. As a result of rail abandonment, farm trucks in the area will be attracted to the nearest facility that has the capability to load grain onto rail cars taking into consideration the distance that must be traveled, and the price for grain available at the elevator.
5. In the case where grain that would have formerly been moved by rail before an abandonment is to be moved by semi trucks, it is assumed that the semi truck will travel toward the same destination had the grain been moved by rail.

6. Calculations

1/ farm truck capacity 425 bushels wheat
530 bushels barley

2/ semi truck capacity 1000 bushels

wheat = 60 lbs/bushel 33 bushels/ton

barley = 48 lbs/bushel 42 bushels/ton

1/ reflects load capacity rather than legal GVW capacity and assumes even mix of single axle and tandem axle farm trucks

2/ reflects load capacity rather than legal GVW capacity and assumes even mix of

(1) semi-truckers with double hopper bottoms 1100 to 1200 bushel capacity

(2) semi-trailers box types temporarily outfitted 800 to 1600 bushel capacity

B. Total increase of semi truck traffic at Butte as a result of rail abandonments:

3. RICHEY-NEWLON JUNCTION

<u>Wheat</u> 75 rail units = 248 truck units annually for increased tonnage of 7,432.

<u>Assume</u>

75% of grain or 5.574 tons is carried by farm truck

25% of grain or 1.858 tons is carried by semi truck to Butte or Lewistown, ID.

<u>Farm Truck</u> (percentages are in total increased tonnage)

35% to Wolf point via P-25*, S-201, and S-254 (2601 tons, 202 truck loads)

25% to Circle via P-51 (1858 tons; 144 truck loads)

10% to Glendive via S-254 (743 tons; 58 truck loads)

%5 to Sidney via P-51 (237 tons; 18 truck loads)

<u>Semi-Truck</u>

25% to Glendive via S-254 (1858 tons; 62 truck loads)

*Note: According to the 1982 Rail Plan (p 5-175) FAP-75 to Wolf Point needs "major work".

RICHEY-NEWLON JUNCTION

0938560 RICHEY
Peavey Company
Richey Elevator

	DEST.	WRU	WRB	WTU	WTB	BRU	BRB	BTU	BTB
11	PNC	8	26,700 1,602,000 lbs. grain 26.7 trucks	14	11,725				
14	CA			43	33,163			1	1,247
16	C-SBS			35	27,611				
23	UT			13	10,785				
24	WY							2	2,627
33	Other MN			19	15,996				
41	MT			93	85,063			12	5,661

RICHEY-NEWLON JUNCTION

0918920 Richey
Farmers Union Trading
Association

	DEST	WRU	WRB	WTU	WTB	BRU	BRB	BTU	BTB
11	PNC	52	171,600 10,296,000 lbs. grain 171.6 trucks	4	3,320				
12	IOW			17	14,848				
16	C-S BS			11	9,549				
24	WY			1	886			6	6,991
31	NW-ST.P.			7	7,115			1	1,275
41	MT	3	9,602 576,120 lbs. grain 9.6 trucks	205	204,739			8	10,021

RICHEY-NEWLON JUNCTION

0917540 LAMBERT
Farms Union Grain Company
of Lambert and Sidney

	DEST.	WRU	WRB	WTU	WTB	BRU	BRB	BTU	BTB
11	PNC	15	49,419 2,965,140 lbs. grain 49.419 trucks						
12	IOW			6	4,886				
13	ID			11	10,232				
16	C-SBS			73	62,090				
31	MN-ST.P			3	2,608				
33	Other MN			3	2,494				
41	MT			6	5,417				

R[illegible]CHEY-NEWLON JUNCTION

0942798 ENID
Enid Grain Company

	DEST.	WRU	WRB	WTU	WTB	BRU	BRB	BTU	BTB
11	PNC			6	5,758				
12	IOW			2	1,663				
16	CSBS			6	5,118				
41				29	28,847				

NO DATA

4. CIRCLE-BROCKWAY

Wheat 12 rail units = 40 truck units annually for increased tonnage of 1,188

Rate of movement

Assume

75% of grain carried by farm truck to Circle

25% of grain carried by semi to Butte or Lewiston

Route A

890 tons - carried by farm track on P-57, S-510

S-467 from Brockway area to Circle (69 truck loads)

297 tons - carried by semi truck via S-253 from Brockway area to Terry and onto I-90 to Lewistown or Butte (10 truck loads)

0917430 Brockway
Farmers Union
Elevator Company
Brockway Elevator

	DEST.	WRU	WRB	WTU	WTB	BRU	BRB	BTU	BTB
11	PNC	12 39.61 trucks 2,376,600 lbs. grain	39,610						
14	CA			6	5,189 311,340 lbs. grain				
16	C-SBS			3	2,503 150,180 lbs. grain				
23	UT			6	5,909 354,540 lbs. grain				
41	MT			22	22,546 1,352,760 lbs. grain				

5. SAPPINGTON-HARRISON

Wheat Nine (9) rail units = 30 track unit annually for increased tonnage of 895

Route of movement

Assume: 10% moves directly off farm to Three Forks
90% moves by semi to Butte or Lewistown

Route A

90 tons = farm truck loads moving on P-13 from Harrison area to Three Forks

805 tons = 27 semi truck loads moving on S-359 to Junction S-259 to Interchange I-90 and west to Lewiston, ID

	DEST.	WRU	WRB	WTU	WTB	BRU	BRB	BTU	BTB
11	PNC	9	29,839 , 1,790,340 lbs. grain 29.839 trucks	47	44,215			11	11,914
12	IOW			4	4,946			1	1,037
13	ID			3	2,625			8	7,698
14	CA			4	3,215			11	10,800
23	UT			1	750			16	15,609
41	MT			2	1,993				

II. Highway impacts as the result of the development of a Butte Subterminal Grain facility.

The Butte subterminal "attraction area" shown on the map includes a sixteen county area described in a previous state study*. The Great Falls and Lewistown-Geraldine areas, although not a part of the original attraction area, have been included as it is believed that a subterminal at Butte may be able to attract grain from these areas. Only the grain that had originally been destined for markets west and south from individual elevators was included in the study. These destinations include:

	Destination Code
North Pacific Coast	11
Interior Oregon and Washington	12
Idaho	13
CCC West	15
Columbia-Snake Barge System	16
California	14
Utah	23

It was assumed (to illustrate drawing potential) that all grain originally headed to the above destinations would be trucked to the proposed Butte Grain Subterminal, from which it can be

* The Montana Department of Agriculture Marketing Unit, "Review of Wheat and Barley Production and Traffic in South Central and Southwest Montana", 25 May 1982.

further transported by truck, the Union Pacific, or the BN railroad to its final market destination.

Highway segments on the map were delineated at population centers of 1000 people or more. The number of bushels to travel over each segment of highway was calculated.

One map overlay shows rail traffic converted to trucks/bushels.

One map overlay shows truck traffic converted to truck/bushels. Arrows on the map show directional movements.

Any time that grain reaches an interstate highway, it then moves directly to Butte.

It was assumed that the number of farm trucks driving directly to Butte would be insignificant.

HIGHWAY IMPACTS

Total production of the Butte drawing area (including Great Falls and the Lewistown-Geraldine areas): 30,489,530 bushels of grain.

In 1982: 11,416,435 moved by truck
19,073,095 moved by rail

The above information is provided by elevator, town, and county in Technical Appendix A.

<u>Note</u>: The information provided in Technical Appendix A. is taken from the Montana Department of Agriculture Grain Movement System reports. This information is confidential and should not be released to the public.

ATTACHMENT C

Effects of Oil Field Development on Low Volume Roadways: An Overlooked Energy Related Cost

By John M. Mason, Jr., Ph.D., P.E.

Over the past decade transportation engineers have addressed numerous energy related costs. Their efforts have traditionally examined alternative techniques to improve the transportation of people and goods, and have generally focused on reducing fuel consumption and improving the overall efficiency of the transportation system. Recently, a different energy related cost has surfaced. This cost is one that is not normally associated with fuel efficiency or petroleum production. It is a cost to resurface, restore, and rehabilitate low volume rural highways that are destroyed by vehicles serving productive oil fields.

The Problem

The rural highways and farm roads in the oil producing counties of Texas were not initially constructed to endure the impact of intense oil field truck traffic. Therefore, a condition of persistent rehabilitation was not anticipated under normal operating situations, and complete pavement restoration costs were not normally accounted for in the planning of maintenance. Since typical traffic characteristics and usual vehicle distributions were not applicable to roadways carrying oil field traffic, it was necessary to determine the definitive elements of the oil field traffic demand.

Traffic volume and vehicle weight are important contributing variables in the design of a roadway pavement. Once the types and number of trucks are established, various traditional methods may be used to determine an adequate and economic pavement thickness. Identification of the vehicle mix and the associated pavement damage was documented and ultimately used to assess the degradation of service.

Previous investigations of roadway pavement deterioration have addressed national and state highway needs. None of the past research has considered the impact of localized traffic. As such, existing methods used to examine roadway rehabilitation needs are deficient in assessing regional impacts created by specialized development. Although the collected traffic data and estimated costs for pavement rehabilitation represent typical conditions on low volume farm-to-market (F.M.) roadways, the study procedure can be used to predict roadway damage costs under similar situations.

Data Collection

Identification of oil field traffic through site specific observation provided the basis for the overall analysis. The study procedure included a description of traffic during the development of an oil well, an estimation of reduction in pavement life under these operating conditions, and an estimate of an increase in annual cost due to a reduced pavement serviceability.

The transportation related activity occurring during the evolution of an oil well was determined through a process of continuous photographic monitoring. Monitoring also included daily site visits to talk with servicing companies and the field representative. The evolution of the well was documented with traffic counts of vehicles entering and leaving the site. Specific information was provided using a super 8-mm camera to photograph vehicles as they entered or left the site (Figure 1). The camera, actuated by a pneumatic tube, signaled individual frame exposures. This procedure provided a count of the number of axles and an identification of vehicle characteristics. A historical evolution of the oi well site was established based on con

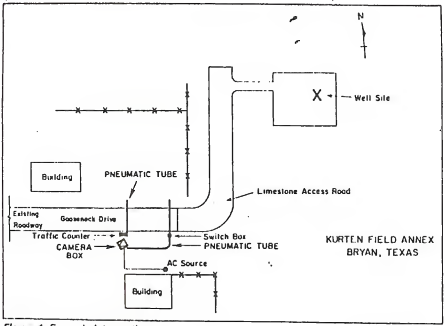

Figure 1. Example Intersections.

Table 1. Vehicles Defined According to Axle Combination and Corresponding Vehicle Type Code.

Axle Combinations	Vehicle Type Code For Axle Combination
Single-Unit Vehicles	
Passenger car	PC
2 Axle-4 Tires (Pickup Truck)	PU-1
2-Axle-6 Tires (Pickup Truck)	PU-2
2-Axle, 6 Tires	SU-1
3-Axle	SU-2
Multi-Unit Vehicles	
2-Axle Tractor, 1-Axle Semitrailer	2-S1
2-Axle Tractor, 2-Axle Semitrailer	2-S2
3-Axle Tractor, 1-Axle Semitrailer	3-S1
3-Axle Tractor, 2-Axle Semitrailer	3-S2
2-Axle Tractor, 3-Axle Semitrailer	2-S3
3-Axle Tractor, 3-Axle Semitrailer	3-S3
2-Axle Truck, 1-Axle Balance Trailer	2-1
2-Axle Truck, 2-Axle Full Trailer	2-2
2-Axle Truck, 3-Axle Full Trailer	2-3
3-Axle Truck, 2-Axle Full Trailer	3-2
3-Axle Truck, 3-Axle Full Trailer	3-3
3-Axle Truck, 1-Axle Balance Trailer	3-1
2-Axle Tractor, 1-Axle Semitrailer, 2-Axle Full Trailer	2-S1-2
3-Axle Full Trailer, 1-Axle Semitrailer, 2-Axle Full Trailer	3-S1-2

versations held at the site with field representatives and on the supplemental photographs taken during the duration of the project.

Traffic Characteristics

The data collected at the oil well site were compiled using a Timelapse 3410 Super 8 projector equipped with a remote control single frame adaptor. Since a frame was exposed upon each axle application, a valid count of axles was possible and daily record of vehicle travel was established.

The various vehicle classifications were tabulated on a standard form. Each day's tabulation was summarized and checked for logical completion, that is, any vehicle entering the site must eventually leave, either the same day or later. Finally, the various stages of development were determined based on the daily log.

Vehicle Classification. Table 1 lists the vehicles serving the study site according to axle combination and corresponding vehicle type code. The vehicle type code was used on a film reduction tabulation and eventually for assigning vehicle load weights to the various axle configurations. Coding of the vehicle type generally followed the AASHTO classification for axle combinations.

A total of 22,923 total single axle repetitions were recorded by the camera. Specific information on the daily traffic pattern is shown in Figure 2. The average daily traffic over the 73 days of camera data was approximately 150 vehicles per day. It should be further noted that this volume is generally considered the typical average daily traffic on a low volume F.M. roadway serving *only its intended-use traffic!*

Distribution of vehicles by code type classification is shown in Figure 3. Passenger cars and pick-up trucks comprised approximately 86 percent of the total vehicle mix; truck combinations approximately 14 percent, with almost 7 percent consisting of the 3-S2 (semitrailer) type. The total truck percentage is almost three times the anticipated truck percentage on low volume F.M. roadways.

Analysis

The axle repetitions of the heavy vehicles occurring during the development of an oil well were used to estimate a reduction in pavement service. Since

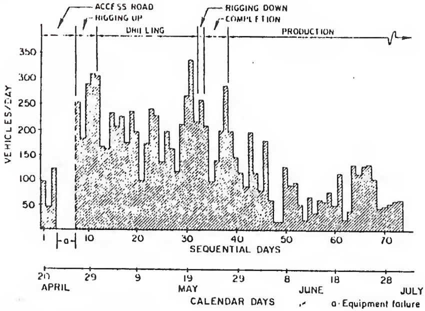

Figure 2. Daily Vehicle Histogram.

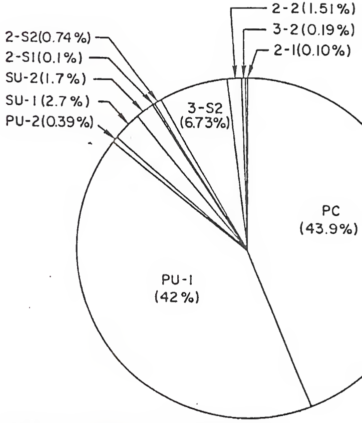

Figure 3. Percent of Vehicles by Code Type Classification.

traffic volume and vehicle weight are important contributing variables in the life of a roadway pavement, the analysis of pavement serviceability was used to assess the degradation of service due to pavement failure.

A concept of "separable costs" was then used to estimate an annual expenditure due to oil field traffic. The attempt was to segregate costs directly attributable to the use of the roadway by a special group of vehicles. It is assumed that these costs would not be incurred if those vehicles did not use the roadway.

Since the time intervals between resurfacing vary considerably among pavement structures, a comparison of costs is difficult unless the costs can be compared on an identical time base. A common and traditional base of comparison used in highway engineering is the calculation of an equivalent uniform annual cost. The annual cost so found, if charged at the end of each year for the assumed life span, will repay the initial investment with interest.

The result of the annual cost comparison is therefore an estimate of separable costs above an intended expenditure. Basically a highway department accepts, and would anticipate, an annual cost associated with the roadway serving its intended purpose. The difference between an anticipated annual cost, and the cost due to increased traffic demand, is the one attributable to oil field traffic.

Three main components of the procedure included a pavement analysis, traffic analysis, and an estimate of traffic generated by an oil well. The conceptual framework is shown in Figure 4. The structural capabilities of a bituminous surface treated pavement were determined for an intended-use situation. Similarly, a projected traffic demand was estimated for a typical low volume F.M. roadway. Respective 18 kip equivalent single axle (18KSA) repetitions were calculated for each analysis. The rehabilitation interval for a bituminous surface treated pavement was then determined. This was done by comparing the estimated cumulative traffic demand with the terminal pavement serviceability of the intended-use pavement section.

Pavement Analysis

Farm-to-market roads are built for an intended-use characterized by low traffic volumes and light weight vehicles.

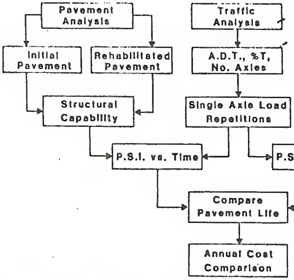

Figure 4. Flow Chart of Analysis Procedure.

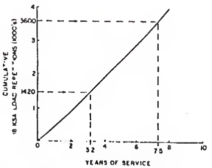

Figure 5. Intended-Use Service Life.

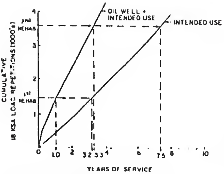

Figure 6. Reduction in Service Life.

These F.M. roads are typically constructed as a bituminous surface treated pavement. This analysis assumed a representative pavement structure of ½-inch crushed stone bituminous surface course (seal coat) over a 6-inch foundation base course. A second ½-inch seal coat served as the intended rehabilitation.

The serviceability-performance concept of the AASHTO Guide[1] was used as the basis for pavement analysis. Pavements under this philosophy are basically designed for a level of serviceability desired at the end of a selected traffic analysis period, or after exposure to a specific total traffic volume.

Comparison of the resurfacing intervals over the design period for the two 18KSA repetitions indicated a reduction in pavement life; therefore, a further comparison was made of the respective total annual costs. The difference between the estimated total annual costs constituted a unit capital loss due to increased traffic, namely, oil field truck traffic. This loss of value represents a consumption, or expenditure of capital, that must be borne by highway departments and the general public. These costs consider only the cost of an initial pavement structure and seal coat resurfacing, and do not include costs associated with a complete pavement reconstruction, vehicle damage, or accidents.

Traffic Analysis

An ADT of 250 was considered representative of a low volume farm-to-market traffic condition. Additional assumptions of traffic conditions follow:

- Percent Heavy Trucks: 1%
- Annual Traffic Growth: 3% per year, and
- Traffic Split: 50/50 on design lanes,
- Axle Loads: Texas loadometer data.

The traffic analysis computations indicated that an estimated 445-18KSA load repetitions can be assumed during the first year of service. Cumulative 18KSA repetitions for an 8-year period are shown in Figure 5. Given the assumptions of the traffic analysis, 1420-18KSA are accumulated after approximately 3.2 years, and 3600-18KSA are accumulated after 7.5 years. These values represent the respective initial life and first seal coat life of a typical F.M. roadway for its intended-use condition. A 2 to 4 year period is generally considered the anticipated life for the initial pavement section of a low volume F.M. roadway. The first seal coat can extend the pavement life to approximately 8 years before additional rehabilitation is necessary.

Determination of 18KSA Repetitions. The observed truck counts were distributed across axle load ranges by their respective percentage distribution. The values correspond to those found in the Texas axle weight tables. This approach prevented biasing the oil truck traffic, since actual axle weights were not taken. The method was considered conservative because it assumed the axle weight distribution of oil trucks was typical of all other truck combinations operating on the Texas highway system. Comparison and interpretation of the findings are therefore on the same basis. (When one reviews the film, it becomes quite apparent that axle loads may actually exceed the typical axle load distributions).

Additional Traffic

Since a typical F.M. road must serve both an intended-use traffic and the attracted oil well traffic, the 18KSA intended-use repetitions were added to the 18KSA oil well repetitions to represent the total 18KSA applications over a study section. It was assumed that the development of the well occurs during the first year of pavement life to allow for full structural benefit from the roadway pavement.

Figure 5 graphically depicts loss of pavement utility. If no additional wells are drilled during the expected service life (7.5 years), the net effect of the drilling and producing of one well is a re-

duced service life of 4.2 years. In another manner, the first rehabilitation is required in year 1.0, rather than year 3.2; the second rehabilitation is needed in year 3.3 versus year 7.5.

Annual Cost Comparison

The annual cost comparison was performed by converting the costs of capital improvements (initial pavement cost) and resurfacing into equivalent uniform annual costs using a capital recovery conversion factor (CRF). The single payment cost for resurfacing, at some specific year in the future, was also considered in the calculation. This is done by means of the single payment present worth factor (PWF).

The annual cost formula for analyzing pavement service life (*4*) is given as:

$$C = CRF_n[I + (R_1 \times PWF_{n_1})] \qquad (1)$$

where

- C = annual cost for pavement per mile,
- n = analysis period (time between initial construction and second resurfacing) in years,
- CRF = uniform capital recovery factor = $$\frac{i(1 + i)^n}{(1 + i)^n - 1} \qquad (2)$$
- I = initial cost of pavement per mile, \$61,100/mile
- R_1 = first resurfacing cost per mile, \$8,600/mile
- n_1 = number of years between initial construction and first resurfacing,
- PWF_{n_1} = single payment present worth factor = $$\frac{1}{(1 + i)^{n_1}} \qquad (3)$$
- i = interest rate = 12%.

The annual cost for a 250 ADT F.M. roadway is \$14,000/mile. The annual cost for a 250 ADT F.M. roadway also serving one (1) oil well is \$26,500/mile. The increase in annual pavement cost is \$12,500/mile. This cost reflects the impact of one oil well on a low volume, light duty F.M. pavement section.

Conclusions

Roadway networks throughout the nation carry numerous types of commercial vehicle traffic. Each commodity shares in the cost of providing an acceptable roadway pavement. The design, or intended-use, of a particular facility will serve its original intent for some period of time. The system can fail due to numerous environmental changes, but it is in serious jeopardy when subjected to a traffic condition well beyond its intended purpose.

Unfortunately, the burden of the associated costs has fallen on state agencies already obligated with a host of maintenance responsibilities. Any attempts at predicting and anticipating needed financial resources and expenditures can aid in the planning and distribution of allocated funds. The analysis procedure developed in this research can also be used to assist in anticipating roadway damage under similar conditions.

While a reduction in pavement life is inevitable on any road, the effects of increased cost should not be ignored in times of financial austerity. If rational analysis is coupled with convincing evidence, the engineer will be able to justify additional allocations to maintain the existing system. Perhaps, if these costs are considered "energy related costs"—they will receive the attention they warrant.

Acknowledgements

This paper has been developed as part of an ongoing research project entitled "Effects of Oil Field Development on Rural Highways" sponsored by the Texas State Department of Highways and Public Transportation. The findings are the result of the Phase I efforts to identify oil field traffic characteristics and estimate the reduction in pavement serviceability on low volume rural farm-to-market roadways. A Technical Advisory Committee acted as an integral part of this study; their continuous guidance and support are greatly appreciated. Special acknowledgement is extended to Dr. N. R. Rowan and Professor C. J. Keese for their encouragement and assistance.

The views, interpretations, analysis, and conclusions expressed or implied in this article are those of the author. They are not necessarily those of the Texas State Department of Highways and Public Transportation.

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Winifred Rail Abandonment   Example of proposed methodology

ADT	X	Directional Factor	X	Percent Trucks	X	18K Load Factor	=	Design Daily 18K E.W.L.
Hilger North designed 1958								
$\frac{220+355}{2}$	X	0.5	X	0.375	X	0.152	=	8.19
Winifred South designed 1960								
$\frac{168.5+290}{2}$	X	0.5	X	0.375	X	0.152	=	6.53

Total Commodity from rail line- lbs.		26,062,000
Average payload of grain truck- lbs./truck	÷	17,270
Round trips required to move commodity	=	1,509
Average Equivalent 18K loading factor	x	0.1886
18K E.W.L. due to 'extra' trucks		284.6

		Hilger		Winifred
'Extra' 18K E.W.L./day		284.6		284.6
Design 18K E.W.L./day	÷	8.19	÷	6.53
Days design life per year lost due to 'extra' 18K loads	=	34.75	=	43.58

Hilger North

Years pavement life with 'extra' trucks (assumes 20 year life without extra trucks) $18.10 = 20 - \left(\frac{34.75 \times 20}{365}\right)$

Years till seal and cover with 'extra' trucks (assumes 10 years without 'extra' trucks) $9.05 = 10 - \left(\frac{34.75 \times 10}{365}\right)$

Winifred South

Years pavement life with 'extra' trucks (assumes 20 year life without 'extra' trucks) $17.61 = 20 - \left(\frac{43.58 \times 20}{365}\right)$

Years till seal and cover with 'extra' trucks (assumes 10 years without 'extra' trucks $8.81 = 10 - \left(\frac{43.58 \times 10}{365}\right)$

$$\text{Annual Pavement Cost} = \text{Capital Recovery Factor} \times \left[\text{Pavement Cost/Mi} + \left(\text{Rehab Cost/Mi} \times \text{Present Worth Factor} \right) \right]$$

Base Case

$$\$12{,}904 = \frac{.12 \times 1.12^{20}}{1.12^{20} - 1} \times \left[93{,}300 + \left(9{,}600 \times \frac{1}{1.12^{10}} \right) \right]$$

Hilger North

$$\$13{,}322 = \frac{.12 \times 1.12^{18.1}}{1.12^{18.10} - 1} \times \left[93{,}300 + \left(9{,}600 \times \frac{1}{1.12^{9.05}} \right) \right]$$

$418 Difference in annual cost per mile due to 'extra' trucks

Base Case

$12,904 Same as above

Winifred South

$$\$13{,}452 = \frac{.12 \times 1.12^{17.61}}{1.12^{17.61} - 1} \times \left[93{,}300 + \left(9{,}600 \times \frac{1}{1.12^{8.81}} \right) \right]$$

$548 Difference in annual cost per mile due to 'extra' trucks

SURFACING DESIGN MANUAL

MONTANA DEPARTMENT OF HIGHWAYS

MARCH 1982

INTRODUCTION

This manual is intended to be a guide for Surfacing Design using the "R" value method to determine the surfacing thickness.

The surfacing design process will follow the Procedure set forth in the Road Design Management Manual.

NOTE: "R" values are determined as set forth in A.A.S.H.O. Designation T 190-66. The exudation pressure used is 300# per S.I.

MONTANA DEPARTMENT OF HIGHWAYS
Policy on items related to "Surfacing Design"

SEAL COAT POLICY

Interstate - Open graded friction course (plant mix seal) will be provided on all new interstate construction and IR work.

Primary - Seal and cover will be the standard treatment on rural Primary projects but open graded friction courses can be provided where deemed appropriate. Conditions which might warrant open graded friction course would include, but not necessarily be limited to very high traffic volumes or a history of seal and cover failure in that particular area.

If there are good reasons for not providing seal and cover or open graded friction course initially one or the other should be shown on the plans as future.

Urban type Primary projects will not receive either seal and cover or an open graded friction course initially.

Secondary - Seal and cover will be the standard treatment on Secondary projects. If there are good reasons for not providing seal and cover initially it will then be shown on the plans as future.

Urban - Because of the complications with curb and gutter and plastic striping neither seal and cover nor open graded friction course will normally be provided on Urban projects. However, either can be considered under unusual circumstances.

Also, seal and cover should be shown on the plans as future.

Small Projects

Seal and cover should not be provided initially but shown as future on small projects. Some judgment must be used in deciding what is a small project but say less than one mile.

STAGE CONSTRUCTION POLICY

Primary: Design for a 20 year period using 0.40' of P.M.B.S. with gravel base and leveling course. The initial stage shall consist of the gravel base and leveling course and 0.25' of the P.M.B.S. The final stage shall include 0.15' of P.M.B.S. plus the amount required for leveling.

Stage construction shall be utilized whenever practical. There will be some cases where our standard 20 year design will be more appropriate.

ENERGY CONSERVATION POLICY

Conservation of energy and materials will be considered in the design of typical surfacing sections.

LOAD FACTOR POLICY

Equivalent 18^k Load Factors will be updated periodically as information is available from the Planning Bureau.

MISCELLANEOUS SURFACING POLICY

Cover aggregate shall generally be ½" gradation.

Load transfer devices may be used in place of Treated Base on short sections of concrete surfacing.

It is our policy to keep the number of typical sections on each project to a minimum, therefore; the minimum length for which a separate typical section is to be designed is 1500'. In special cases, where the subgrade support value varies radically, exceptions could be made.

ESTIMATING DATA

Plant Mix Bituminous Materials - 128.5# per tenth per s.y. + 5% contingency.

Asphalt Cement for Plant Mix Bituminous Materials

Grade A = 6.5% x weight of plant mix material
Grade B = 6.5% x weight of plant mix material
Grade C = 6.5% x weight of plant mix material
Grade D = 6.5% x weight of plant mix material
Plant Mix Base Gr. 1 - 6% x weight of plant mix material
Plant Mix Base Gr. 2 - 6% x weight of plant mix material

Asphalt Cement for Road Mix Bituminous Materials - 7% x weight of aggregate.

Prime - 0.3 gal. of liquid asphalt per s.y.
Tack - 0.05 gal. of liquid asphalt per s.y.
Seal - 0.35 gal. of liquid asphalt per s.y.
Aggregate for cover material - 25# per s.y.

Mineral Filler for Plant Mix = 1½% x weight of plant mix material.

Aggregate Surfacing = 3700# compacted weight per c.y. + 5% contingency.

Rolling for Aggregate Surfacing = 0.005 Units per Ton.

Water for Aggregate Surfacing = 0.025 M. Gal per Ton.

Rolling Cover Aggregate = 0.04 Units per Ton.

Double Bituminous Surface Treatment

Aggregate first application = 30# of 3/4" Gr. 1 per s.y.
Aggregate second application = 25# of ½" Gr. 3 per s.y.
Bituminous material first application = 0.40 gal. per s.y.
Bituminous material second application = 0.35 gal. per s.y.

Open Graded Plant Mix Seal

Aggregate = 70# of 3/8" (open graded) per s.y.
Asphalt Cement - (85-100 Pen.) = 7% x weight of aggregate.
Tack Coat - 0.05 gal. per s.y.

These quantities will provide a nominal thickness of approximately 3/4". A 20% contingency should be added on jobs placed over an old roadway to allow for the uneven surface.

This estimating data is to be used unless specifically advised otherwise.

EFFECTIVE DATE - March 1982

CHARTS AND TABLES

The following charts and tables are to be used in the design of the Surfacing for Montana Highways.

CONVERSION TABLE

Table #1

Equivalent 18,000# Axle Loads to Traffic Index

Range of Equivalent Daily Load Application			T.I.
0	.34	-	4.0
.35	.53	-	4.2
.54	.78	-	4.4
.79	1.13	-	4.6
1.14	1.64	-	4.8
1.65	2.38	-	5.0
2.39	3.45	-	5.2
3.46	4.99	-	5.4
5.00	7.11	-	5.6
7.12	9.9	-	5.8
10.0	13.6	-	6.0
13.7	18.3	-	6.2
18.4	24.3	-	6.4
24.4	31.8	-	6.6
31.9	41.2	-	6.8
41.3	53	-	7.0
54	68	-	7.2
69	86	-	7.4
87	110	-	7.6
111	140	-	7.8
141	175	-	8.0
176	215	-	8.2
216	269	-	8.4
270	335	-	8.6
336	410	-	8.8
411	500	-	9.0
501	609	-	9.2
610	740	-	9.4
741	895	-	9.6
896	1075	-	9.8
1076	1290	-	10.0

TO ESTABLISH EQUIVALENT DAILY 18^k SINGLE AXLE LOAD APPLICATIONS

Assume Interstate Highway

Traffic Data from Planning Survey

Assume Year 1981 = 935 A.D.T.
Year 2006 = 2950 A.D.T.

EXAMPLE PROBLEM

10.5% Comm. Trucks
9.6% Panels & Pickups
20.1% All Trucks

Assume letting date is 1983 then convert traffic to 20 yrs. after letting date:

$$\begin{array}{rr} 2006 = & 2950 \\ \underline{1981} = & \underline{935} \\ 25 & 2015 \end{array}$$ increase - divide by No. of Years 25 = 80.6 per year increase

$$\begin{array}{r} 1983 \\ \underline{-1981} \\ 2 \text{ Yr.} \end{array}$$ 2 x 80.6 = 161 + 935 = 1096 A.D.T. = year 1983

$$\begin{array}{r} 2006 \\ \underline{2003} \\ 3 \text{ Yr.} \end{array}$$ 3 x 80.6 = 2950-242 = 2708 A.D.T. = year 2003

1983 = 1096 A.D.T.
2003 = 2708 A.D.T.
20 3804 ÷ 2 = 1902 A.D.T. Ave. 20 Yr. for design

1902 A.D.T. x .50 directional factor x 0.201 percentage of trucks x 421.4 per 1000 load factor = 80.6 Equiv. 18,000 Wheel loads.

NOTE: On high volume multilane facilities, for design purposes, assume the following percentages of trucks in the design lane.

20-Year Design A.D.T.		
4,000 or less A.D.T.	-	100% Trucks in design lane
4,000 to 8,000 A.D.T.	-	95% Trucks in design lane
8,000 to 12,000 A.D.T.	-	90% Trucks in design lane
12,000 to 20,000 A.D.T.	-	85% Trucks in design lane

SURFACING COEFFICIENTS FOR STRUCTURAL COMPONENTS

	"R" Value 70 or Greater PER INCH	"R" Value 60-70 PER INCH	"R" Value 70 or Greater PER FOOT	"R" Value 60-70 PER FOOT
SURFACING COURSES				
Plant Mix Grade A	0.33	0.30	4.0	3.6
Plant Mix Grade B Primary & Interstate	0.33	0.30	4.0	3.6
Plant Mix Grade C Secondary	0.31	0.28	3.7	3.4
Plant Mix Grade D	0.31	0.28	3.7	3.4
Road Mix	0.20	0.18	2.4	2.2
Crushed Gravel	0.12	0.10	1.4	1.2
TREATED BASE COURSES				
Plant Mix Base Grade 2	0.30	0.28	3.6	3.4
Plant Mix Base Grade 1	0.25	0.22	3.0	2.6
Bituminous Stabilized	0.20	0.18	2.4	2.2
Cement Treated +400 p.s.i. at 7 days	0.20	0.18	2.4	2.2
Cement Treated -400 p.s.i. at 7 days	0.15	0.14	1.8	1.7
Lime Treated	0.15	0.14	1.8	1.7
GRAVEL BASE COURSES				
Crushed Gravel 1½" Max.	0.12	0.10	1.4	1.2
Crushed Gravel over 1½"	0.11	0.09	1.3	1.1
Selected Surfacing	0.10	0.08	1.2	1.0
Special Borrow	0.07	0.06	0.8	0.7
Sand Surfacing	0.05	0.05	0.6	0.6

EQUIVALENT 18^k LOADING FACTOR

Secondary	188.6	per	1,000
Primary	200.2	per	1,000
Interstate	421.4	per	1,000

NOTE: In special cases where there is reason to believe the load factor is substantailly different than the statewide average a detailed study may be made to determine a more realistic 18^k loading factor.

MINIMUM DESIGN CRITERIA

20 Year Design

The following "Total Structural Numbers" are the minimum total design S.N. to be used for the various types of surfacing section.

INTERSTATE	2.45 SN
PRIMARY	1.95 SN
SECONDARY	1.65 SN

The following are the minimum thickness of the various types of surfacing materials to be used.

			ASPHALT	CONCRETE
SURFACE COURSE	INTERSTATE	=	0.35'	8"
	PRIMARY	=	0.25'	7"
	SECONDARY	=	0.20'	7"

			CRUSHED GRAVEL
LEVELING COURSE	INTERSTATE	=	0.20'
	PRIMARY	=	0.15'
	SECONDARY	=	0.15'

		ASPHALT	TREATED SOILS	CRUSHED GRAVEL
INTERSTATE	=	0.35'	0.35'	0.50'
PRIMARY	=	0.35'	0.35'	0.50'
SECONDARY	=	0.35'	0.35'	0.50'

NOTE: The minimum Plant Mix Bituminous Surfacing may be reduced to 0.15' on Full Depth Asphalt sections.

MINIMUM DESIGN CRITERIA

Stage Construction

Primary: Our policy is to design for a 20 year period using 0.40' of Plant Mix Bituminous surfacing with a seal coat, gravel base, and leveling course. The first stage shall include the gravel base and leveling course and 0.25' of P.M.B.S. with a seal coat plus the amount of P.M.B.S. required for leveling.

Secondary: Our policy is to design for a 20 year period using 0.35' of Plant Mix Bituminous surfacing with a seal coat, gravel base and leveling course. The first stage shall include the gravel base and leveling course and 0.20' of P.M.B.S. with a seal coat. The second stage will be 0.15' of P.M.B.S. with a seal coat plus the amount of P.M.B.S. required for leveling.

On Full Depth Asphalt Sections the first stage is to be P.M.B.B. or P.M.B.S. with a seal coat. The second stage will be 0.15' P.M.B.S. with a seal coat plus the amount of P.M.B.S. required for leveling.

FLEXIBLE SURFACING
DESIGN CALCULATION PROCEDURE

The following is an example of the calculations for the design of a flexible pavement structure:

1. Establish serviceability index and the traffic analysis period to be used in design:

   In this example assume:
   Serviceability index = 2.5
   Traffic analysis period = 20 years

2. Traffic data:

   As received from planning survey. Year 1981 = 935 A.D.T., 2006 = A.D.T. 20.1% (All Trucks). Directional Factor 50%-50%, all traffic in design lane. Convert this information to T.I. (Traffic Index) and equivalent daily 18^k single load applications, as per Page 4 and Page 5.

3. Determine from the soils profile and laboratory tests the "R" Value for the subgrade.

   In this example assume:
   "R" Value = 20
   Cover required = 1.9' (uncorrected) as determined from Chart #1 Page 10
   Type of soil = A-4(1)

4. Determine SN from design chart #3 Page 12. Place straight edge on 20 "R" Value and on 81 equivalent daily 18^k scale then read the SN number. The SN number is further refined by projecting through the Regional Factor Scale (usually 2.5) and reading the final SN number on the SN. Weighted Structural Number Scale. In this example the SN = 3.05

5. Assume in this example that the pavement is part of the Interstate System. Our minimum gravel section for the system is 0.50' of Crushed Gravel Base, 0.2' of Leveling Course and 0.35' of Hot Plant Mix Surfacing for a total minimum thickness of 1.05'.

6. Convert the weighted SN of 3.05 to a design thickness consisting of gravel with an asphaltic surface. Coefficients are from Page 6.

ITEM	DEPTH		COEFF. PER FT.		STRUCTURAL NO. (SN)
Plant Mix A.C. Grade B	0.35'	x	4.0	=	1.40
Leveling Course - 3/4"	0.20'	x	1.4	=	0.28
Crushed Gravel Base - 1½"	0.50'	x	1.4	=	0.70
	1.05' TOTAL		TOTAL SN		2.38

NOTE: This section would not meet the requirements for corrected cover or SN and would have to be recomputed using a thicker section.

Using the method shown above adjust the thickness until the 3.05 SN and cover is satisfied. Then proceed on the same basis and design a full depth and full strength asphalt section for comparison. After the most acceptable flexible section has been determined design the most acceptable rigid section and make a cost comparison of the alternate designs. The cost comparison and design information is submitted as set forth in the "Procedure" for Surfacing Design.

RIGID SURFACING
DESIGN CALCULATION PROCEDURE

Charts 4 & 5, Pages 13 & 14 are used to quickly determine approximate designs. If a more detailed comparison is indicated the design is prepared using the "P.C.A. Thickness Design for Concrete Pavements".

DESIGN CHART FOR THICKNESS OF LAYERS OF PAVEMENT STRUCTURE

PROCEDURE FOR USE OF CHART

The chart solves the following formula:

$$T = \frac{0.0032\,(TI)\,(100-R)}{G_f}$$

With a straightedge through Scale E at the R-value (R) of the soil tested and Scale F at the design Traffic Index (TI), intersect Scale G. Scale G is a turning point on the nomograph and indicates the thicknesses of gravel cover needed to sustain the design T.I. with the cohesion or slab value of the pavement neglected. From that point on Scale G, intersect Scale H at the combined gravel equivalent factor of the layers above the material in question. The intersection with Scale I determines the required thickness (T) corrected for the slab value of the upper layers of cover material needed to prevent plastic deformation of the soil tested.

EXAMPLE

Given:

R-value of a soil = 31
TI = 8.0
G_f = 1.5

Answer:

Thickness of cover (T) = 1.20'

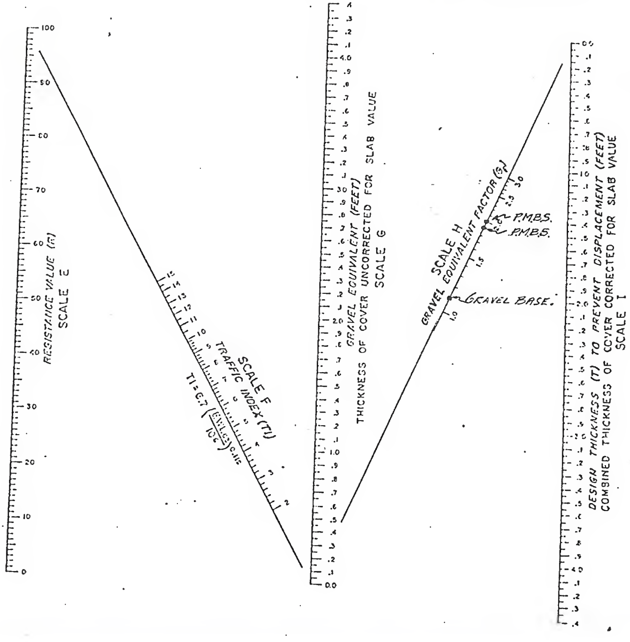
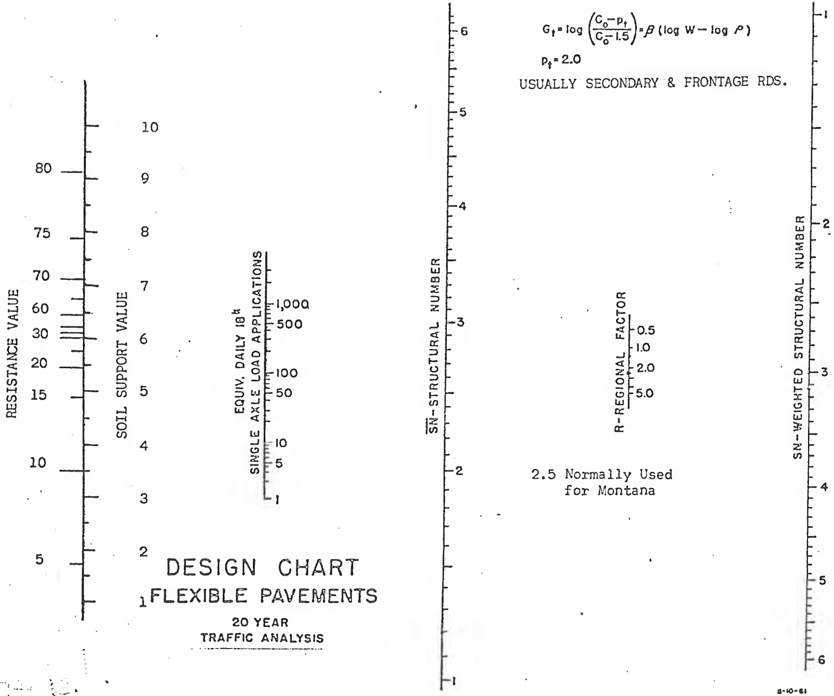


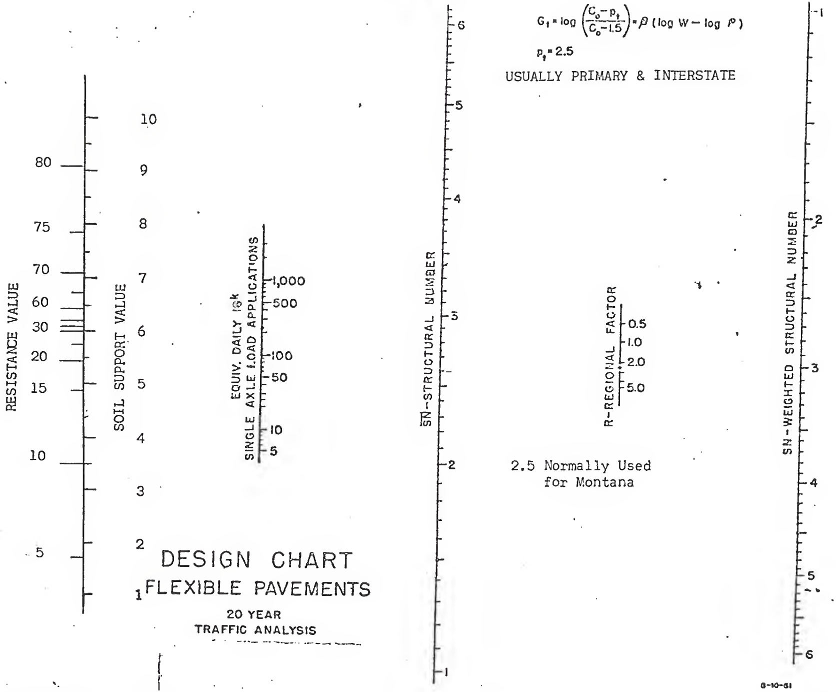
CHART 1

CHART 2



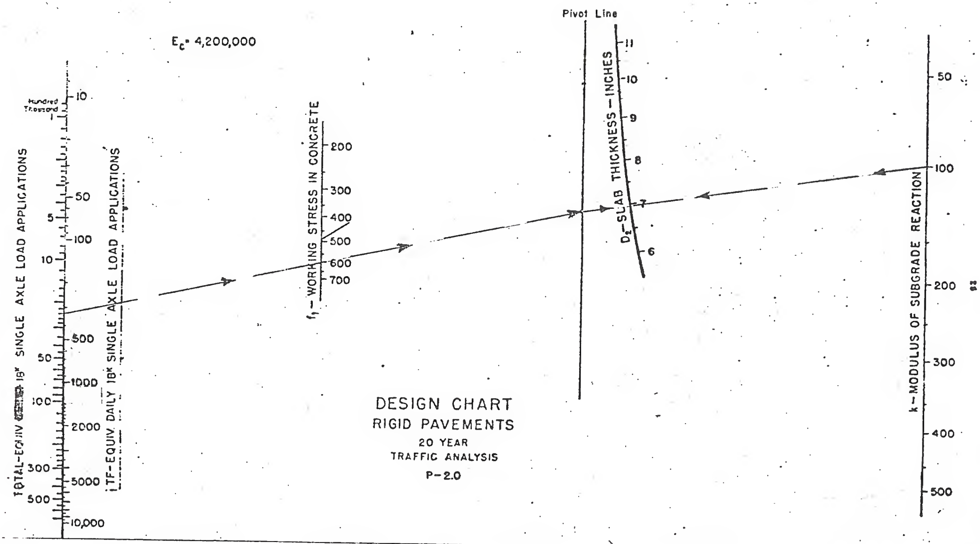
$G_t = \log\left(\frac{C_o - p_t}{C_o - 1.5}\right) = \beta(\log W - \log \rho)$
$p_t = 2.0$
USUALLY SECONDARY & FRONTAGE RDS.
RESISTANCE VALUE
80
75
70
60
30
20
15
10
5
SOIL SUPPORT VALUE
10
9
8
7
6
5
4
3
2
1
EQUIV. DAILY 18k SINGLE AXLE LOAD APPLICATIONS
1,000
500
100
50
10
5
1
$\overline{SN}$-STRUCTURAL NUMBER
6
5
4
3
2
1
R-REGIONAL FACTOR
0.5
1.0
2.0
5.0
2.5 Normally Used for Montana
SN-WEIGHTED STRUCTURAL NUMBER
1
2
3
4
5
6
DESIGN CHART
FLEXIBLE PAVEMENTS
20 YEAR
TRAFFIC ANALYSIS
8-10-81

CHART 3



$G_t = \log\left(\frac{C_o - p_t}{C_o - 1.5}\right) = \beta\,(\log W - \log \rho)$
$p_t = 2.5$
USUALLY PRIMARY & INTERSTATE
RESISTANCE VALUE
80
75
70
60
30
20
15
10
5
SOIL SUPPORT VALUE
10
9
8
7
6
5
4
3
2
1
EQUIV. DAILY 18k SINGLE AXLE LOAD APPLICATIONS
1,000
500
100
50
10
5
$\overline{SN}$-STRUCTURAL NUMBER
6
5
4
3
2
1
R-REGIONAL FACTOR
0.5
1.0
2.0
5.0
2.5 Normally Used for Montana
SN-WEIGHTED STRUCTURAL NUMBER
1
2
3
4
5
6
DESIGN CHART
FLEXIBLE PAVEMENTS
20 YEAR
TRAFFIC ANALYSIS
8-10-61

CHART 4

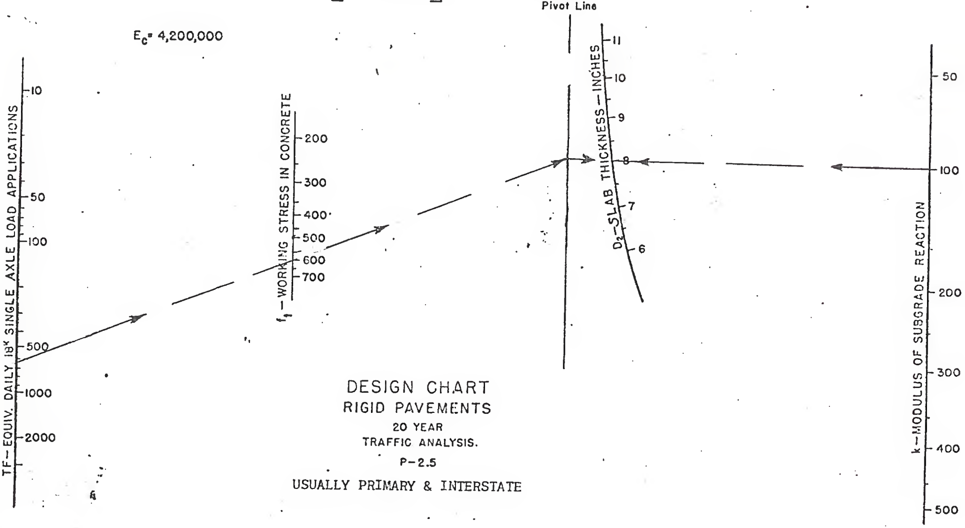


USUALLY SECONDARY

$$\log W_1' = \log(7300\,TF) = 7.35 \log(D_2+1) - 0.06 - \left[\frac{0.176}{1+\frac{1.624 \times 10^7}{(D_2+1)^{8.46}}}\right] + 3.42 \log\left[\frac{f_1}{690}\left(\frac{D_2^{0.75}-1.132}{D_2^{0.75}-0.407\,k^{0.25}}\right)\right]$$

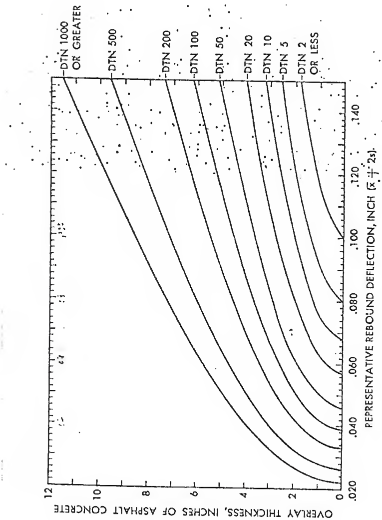
$E_c = 4{,}200{,}000$

CHART 5



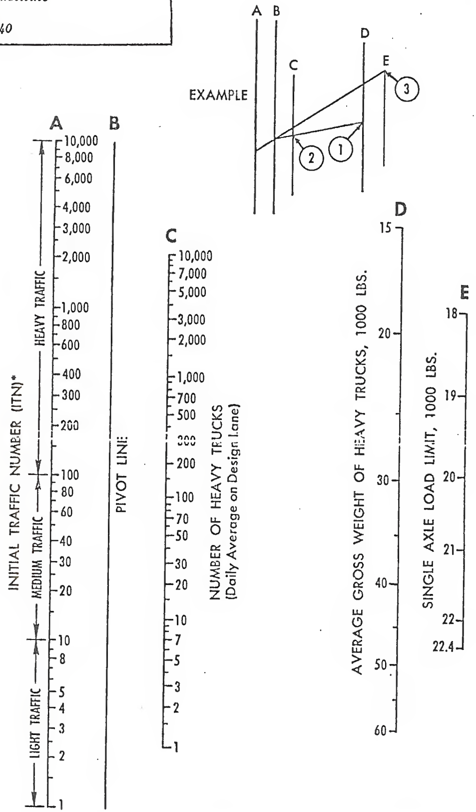
DESIGN CHART
RIGID PAVEMENTS
20 YEAR
TRAFFIC ANALYSIS.
P-2.5

USUALLY PRIMARY & INTERSTATE

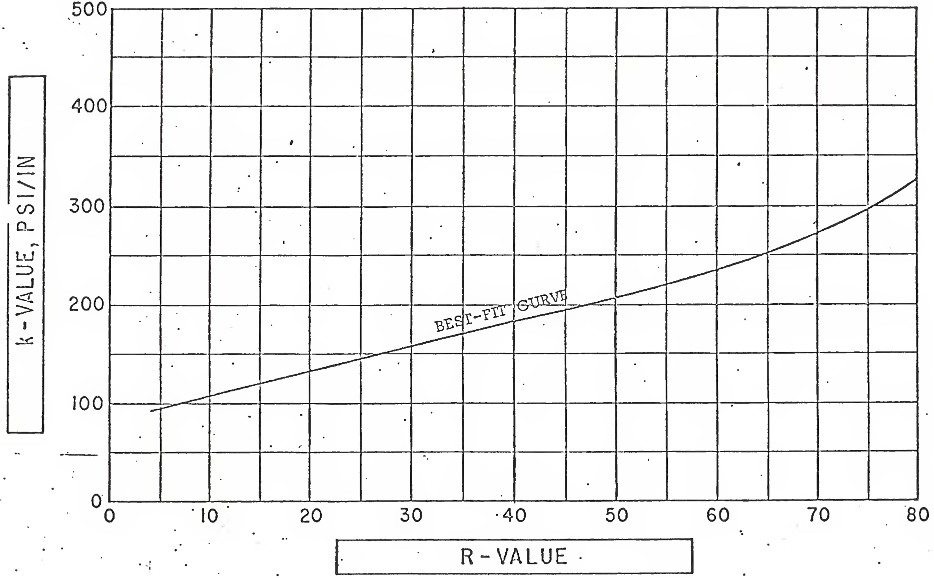


—Asphalt concrete overlay thickness required to reduce pavement deflection from a measured to a design deflection value (rebound test)

From THICKNESS DESIGN Manual (MS-1)
Eighth Edition
The Asphalt Institute
College Park
Maryland 20740



* ITN value may require correction where the IDT of automobiles and light trucks is relatively high. See Figure III-2



k-VALUE VS R-VALUE